

# Study on AC Contactor Performance Under Voltage Sags

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**Abstract:** AC contactor many found in industrial sectors. Its function is to link induction motor to utility supply and recognized susceptible to voltage sags. The contactor consists of primary and auxiliary contacts. The primary contact can be opened if it is supplied by voltage sags. In an industry, a contactor is used to keep electric motors abruptly restart when the voltage sag returns to normal. This study discusses the behaviour of three contactors caused by voltage sags and interruption. The contactors are fabricated from different manufacturers. Voltage sag characteristics used are sag magnitude, sag duration and also point on wave (POW) of sag initiation. The testing results show that the contactor performances are greatly influenced by them. The contactors are more susceptible when they were served with deeper and longer voltage sag. Susceptibility of contactors to sag duration rises when they were supplied by voltage sags with the POW near to 90°. The contactor susceptibilities decrease when the sag occurs at three POWs which are 0°, 45° and 90°.

**Keywords:** Contactors performance, sag magnitude, sag duration, point on wave of sag initiation

## 1. Introduction

Voltage sag caused by short circuit fault in power system. The large current resulted propagates to all network causes large voltage drop so the terminal voltage at receiving end to be decrease. According to IEEE Std. 1159 (1995) voltage sag is reduced voltage in magnitude from 90% to 10% of nominal voltage with sag duration from 0.5 cycles until one minute. If the magnitude of voltage sag is lower than 10% is called as interruption. Sag duration is time difference between the start and end of voltage sag. Phase angle of the sinusoidal voltage which the voltage sag starts to happen is called POW of sag initiation. Sag magnitude and sag duration are primary characteristics of voltage sags. Those characteristics have great effect on susceptibility of equipments (Bollen, 2000) and (Dugan, R. C., et al. 2003).

Electrical contact of contactor will close when electromagnetic force larger than spring pressure. The force is influenced by voltage supply magnitude that connected to magnetic coil so that produce current. When contactor to close contact needs larger current than current required to withstand them in normal condition. Electromagnetic force decreases when the contactor is supplied voltage sags. A contactor will drop out when magnitude of electromagnetic force is lower than spring force. The spring leads to the contact retain in open position so current flows to induction motor interrupted. Contactor many found in industrial sector that work to connect and disconnect from supply voltage to prevent motor from suddenly restarting when the voltage back to normal.

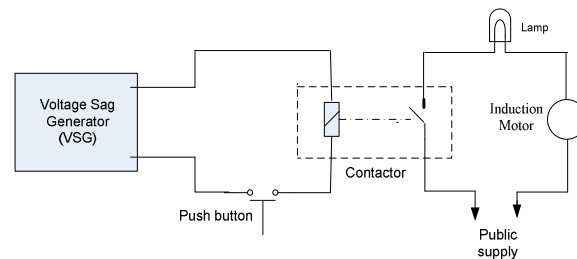
In previous studies, research take into account POW of sag initiation on contactor testing through experimental found in (Pohjanheimo, P. and M. Lehtonen, 2002) and (Iyoda, et al.

2007). The studies take into consideration the POW in two values only which are  $0^\circ$  and  $90^\circ$ . S.W et al. 2009 propose the POW  $0^\circ$  until to  $90^\circ$  in simulation model. The POW increases from  $0^\circ$  to  $90^\circ$  by step of  $15^\circ$ . The POW have influence on contactor behaviour to drop out.

## 2. Testing Of Contactor

Three contactors with appellation A, B and C are tested by an experiment at CERE laboratory in UniMAP. Those contactors have the same rating voltage and frequency but are manufactured from different plants. The experiment is displayed such as in Figure 1.

The contactor was supplied by an equipment SchaffnerProflin2100 Electromagnetic Compability. Many types power qualities can be produced by this equipment. One of them are voltage sag. Out put of voltage sag generator (VSG) can be adjusted to find voltage sag characteristic desired.



**Fig. 1.** Schematic circuit of experiment

A 0.5hp induction motor was used as load. A 25W incandescent lamp was used as indicator which it will off when the contactor drop out. The both devices were connected to public supply. The test procedure as follow;

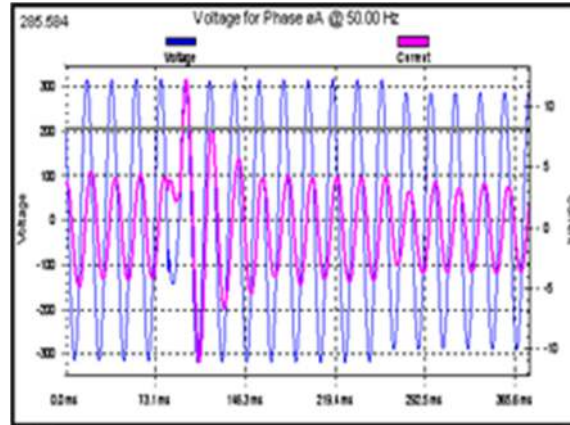
- (i) The experiment is beginning with out put of VSG is set to 70% of nominal voltage,  $0^\circ$  the POW and sag duration of 10ms. The sag duration is increased by step of 10 until 200 milliseconds. Record the contactor did not drop out or drops out.
- (ii) Sag magnitude reduced in step of 2.5% until 0% and then action in point (i) is replayed. The test is replayed 2 until 3 time to prevent error due to random diversity.
- (iii) Repeat point (ii) for distinct the POW with increment of  $15^\circ$  to  $90^\circ$ .

## 3. Test Results

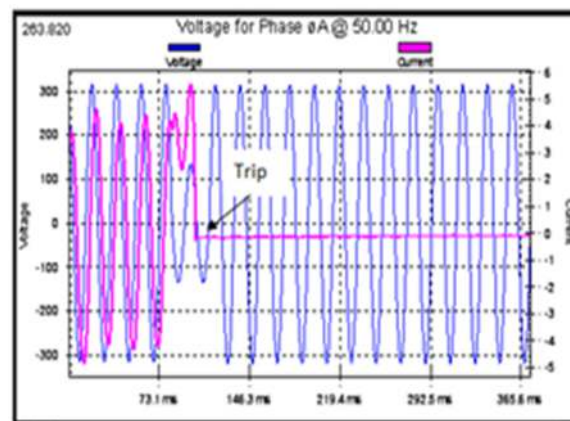
### 3.1 Contactor performance caused by voltage sag magnitude

Implementation of contactor C when it was supplied by voltage sag in distinct characteristics is shown in Figure 2.. These figures are line voltage supplied and current waveform through contactor.

Figure 2 (a) illustrates contactor C when supplied by sag magnitude of 60% and sag duration of 100 milliseconds. The contactor did not drop out and current waveform still oscillation in horizontal axe. Figure 2 (b) illustrates the contactor was supplied by lower sag which is 45% sag magnitude in same duration. The current still oscillation in a few cycles and then toward zero and it did not direct drop out. The performance contactor drop out is indicated by current waveform. From Figure 2, contactor is more susceptible when it supplied by lower sag magnitude.



(a) 60% sag magnitude, 100milliseconds sag duration



(b) 45% sag magnitude, 100milliseconds sag duration

**Fig. 2.** Voltage and current waveforms for contactor C.

### 3.2 Effect of magnitude and duration of voltage sag

Figure 3 is one of three susceptible curves of the contactors. There are four different points for investigating namely P, Q, R and S. Point P at (50%; 40 milliseconds), Q at (40%; 40 milliseconds), R at (20%; 40 milliseconds) and S at (20%; 80 milliseconds).

Positions of P and Q located in same sag duration (40 milliseconds), but they have distinct sag magnitude which are 50% and 35%, respectively. The point P indicates contactor response remains operated while at point Q the contactor dropped out. Position Q is deeper sag than P. Points R and S located at same magnitude of 20%, but distinct in sag duration. Response of the contactor at those points is not similar. At point R the contactor did not drop

out at (20%; 40 milliseconds) whereas S indicates that the contactor is in dropping out condition at (20%; 80 milliseconds).

Mostly equipments are more susceptible if they are subjected to deeper voltage sag and longer sag duration. This is also similar to study conducted by (George, et al. 2005) which they susceptibilities increased when they were supplied to deeper voltage sag and longer sag duration.

### 3.3 Effect of point on wave of voltage sag initiation

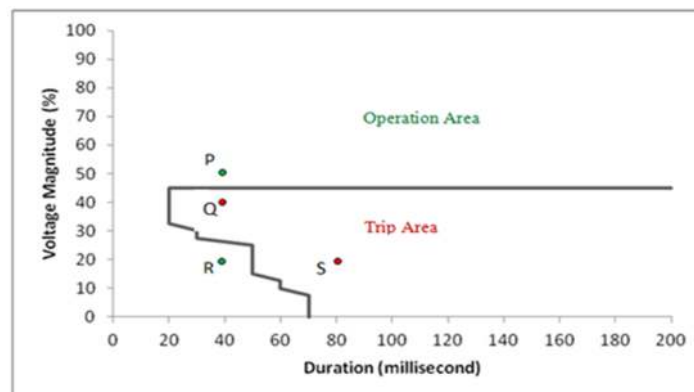
Phase angle point of sinusoidal fundamental wave where voltage sag beginning occur is called POW of voltage sag initiation. In this study the POW take into account are 0°; 15°; 30°; 45°; 60°; 75°; 90°. Susceptibility curves resulted of testing in some POW are presented through Figure 4 until to Figure 6. The curves indicate susceptibilities values of contactors which they drop out. The contactor A has threshold voltage value is highest for POW of 30° and 60° such as in Figure 4. Highest value of the threshold voltage

is 40%. Susceptibility of contactor against sag magnitude decreases for other POWs. Values of POWs of 0°, 75° and 90° causes threshold magnitude voltage value decrease become to 30%, 30% and 20%, respectively. Contactor is most susceptible to sag duration while it supplied by 75° and 90° the POWs. Value of sag duration is 20 milliseconds. In other word, 20 milliseconds is lowest value for sag duration.

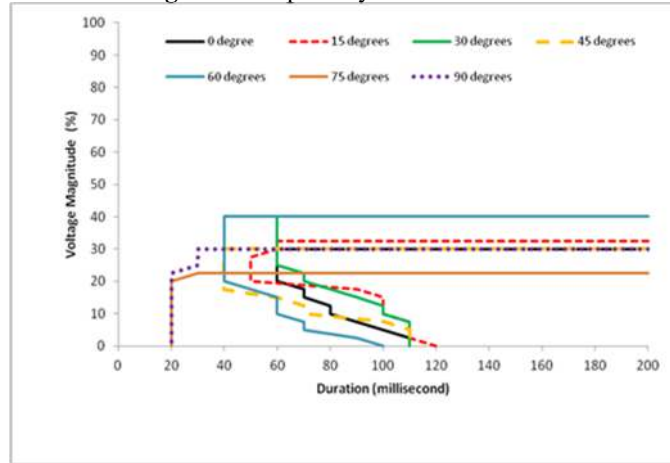
Figure 5 indicates susceptibility of contactor B. Highest and lowest susceptibilities to voltage magnitude were achieved when the contactor was supplied by the POW of 60° and 90°, respectively. The threshold values are 47.5% and 30% of nominal voltage. For sag duration, highest susceptibility the contactor was obtained at 20 milliseconds when it was supplied by POWs of 75° and 90° but the threshold voltage are not similar.

Contactors C produce results for same sag duration in some the POW such as in Figure 6. It drops out at sag duration of 20 milliseconds. It can be seen that the contactor is most susceptible to voltage magnitude when it was supplied by 60° the POW. The voltage magnitude value is 55%.

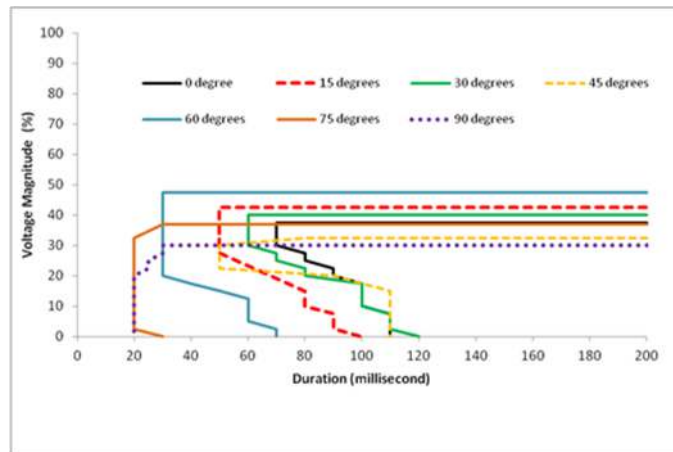
Investigation in Figure 4 until to Figure 6, contactor to drop out is not similar, however curves of the susceptibility showing the pattern is almost the similar. In general susceptibility curves of three contactors are almost horizontal in sag magnitude whereas for sag duration are not vertical. Consequently the susceptibility curves are not rectangular. These indicate that susceptibility of contactors are affected by point of wave of voltage sag initiation. Contactors drop out for sag duration are equal or greater than 20 milliseconds.



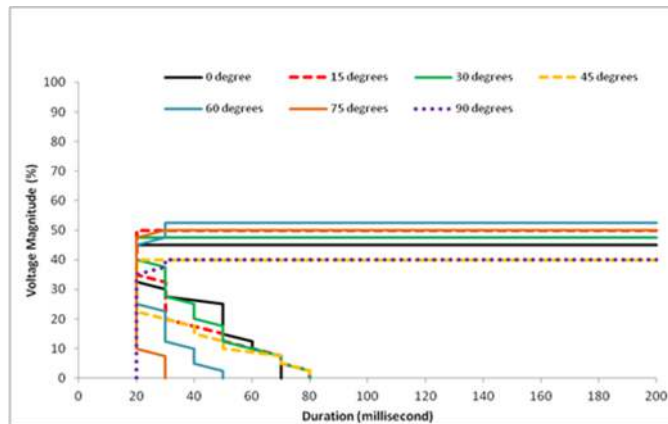
**Fig. 3.** Susceptibility curve of a contactor



**Fig. 4.** Susceptibility curves of contactor A in distinct POWs of sag initiation

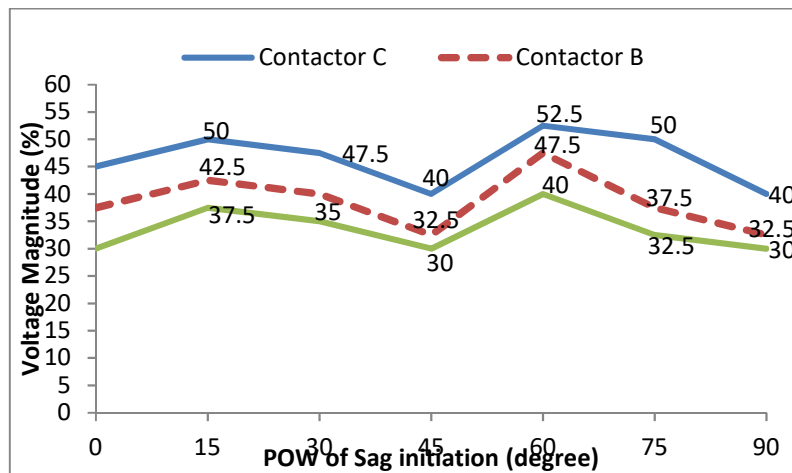


**Fig. 5.** Susceptibility curves of contactor B in distinct POWs of sag initiation

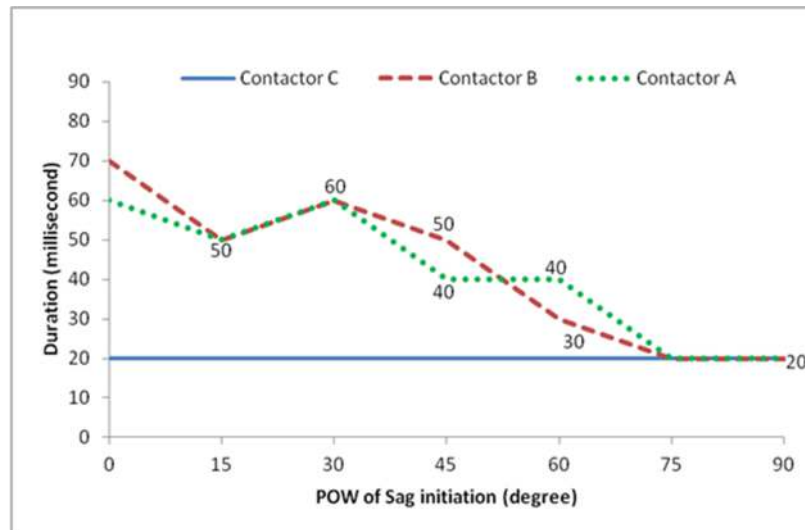


**Fig. 6.** Susceptibility curves of contactor C in distinct POWs of sag initiation

Figure 7 illustrates susceptibility points in distinct POW. Figure 7 (a) is susceptibility points of contactors against sag magnitude. They susceptibility decrease for POW of 0°, 45° and 90°. From this figure can be also explained that three contactors have contactor A. Figure 7 (b) illustrates effect of POW on sag duration. Two contactors (A and B) to be faster to drop out when it was supplied by the POW of 90°. causes contactors to be more susceptible to drop out. Susceptibility of contactor C to sag duration some susceptibility curve is almost similar with up and down pattern. Sag magnitude with POW of 60° causes contactors to be more susceptible to drop out. Order of the most susceptible are contactor C, contactor B, the POWs are constant which it drops out at 20 milliseconds and it is not effected by POW. Three contactors have similar susceptibility for POW of 75° and 90° and they threshold values are 20 milliseconds.



(a) Sag magnitude in distinct the POW



(b) Sag duration in distinct the POW

Fig. 7. .Susceptibility points in distinct the POW

#### 4. Conclusion

Contactors performance under voltage sags for drop out are not not similar. But the susceptibility curves show are almost similar pattern. The curves in horizontal axes are flat but they are not flat in vertical axes. Even for lower sag, required time for the contactors drop out are longer. These are caused by effect of the POW. Three contactors have same threshold values against sag duration which are 20 milliseconds. The susceptibility curves of the contactors against sag duration decreases when the voltage sags occur with the POW near to 90°. Contactors are most susceptible against sag magnitude for the POWs of 15° and 60° whereas for POWs of 0°, 45° and 90° POW susceptibility decrease.

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